


Current and Future Areas of Nuclear Safety Research in Germany

27th Annual Regulatory Information Conference (RIC)
Future Direction of International Research for Reactors and Fuel Cycle Safety

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12 March 2015




Introduction (1)


Changed Political Framework Conditions in Germany

- 13th Amendment of the **Atomic Energy Act** came into force on August 6th 2011:
 - granted lifetime extensions were revoked
 - licenses of the 7 oldest NPPs and of the Krümmel BWR expired
 - shutdown of the remaining 9 NPPs until 2022 after generation of specifically determined amounts of electricity

⇒ re-orientation of **nuclear safety research in Germany**:
alignment with national and international framework conditions and obligations



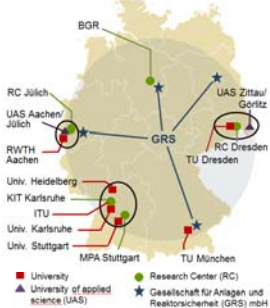
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Introduction (2)

Alliance of Competence in Nuclear Technology

- Centered around research centers:
 - Karlsruhe
 - Jülich
 - Dresden-Rossendorf
 - GRS
- Aims:
 - platform for scientific exchange among partners
 - programmatic orientation to its members and to the ministries funding the research
 - global agreement on appropriate task sharing among the partners
- In spring 2013, the evaluation report on nuclear safety research was published
 - ⇒ re-orientation along **6 strategic research areas**



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Strategic Re-Orientation of Nuclear Safety Research (1)

1) **Research to support safety during the remaining operation of German NPPs and research reactors**

- methods and computational tools for safety analysis and assessment (e.g. **multi-physics simulation codes, PSA**, uncertainty- and sensitivity analysis, severe accident analysis, SAMG)
- improved methods for structural integrity assessment
- improved characterisation of extreme natural hazards
- methods for human factor and organisational analysis (e.g. human behaviour under accident conditions)
- fast running tools for the use in emergency centres and support systems for decision making by authorities

2) Safe decommissioning and dismantling of NPPs

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Strategic Re-Orientation of Nuclear Safety Research (2)

3) Safe long-term interim storage and final disposal of radioactive waste

- **safety of final repositories** (e.g. methods and tools for the demonstration of the safety case)
- behaviour of spent fuel during long-term interim storage
- studies on efficient and safe partitioning / transmutation of actinides (international collaboration)

4) Methods and tools for the safety analysis of advanced reactor concepts pursued internationally (Gen IV, SMR)

- assess and promote the safety of nuclear plants developed and built abroad,
- international collaboration (e.g. OECD NEA, IAEA, etc.)

5) Scientific support to the development of internat. requirements and standards in nuclear safety (safety criteria for digital I&C, quantification of hazards)

6) Improved safeguards techniques

- further development of safeguards technologies (electronic seal and camera systems, long-distance data transmission, satellite remote sensing and geographical information systems, measuring methods to analyse environment samples and nuclear materials etc.)

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Selected Results (1)

Multi-physics Simulation Tools

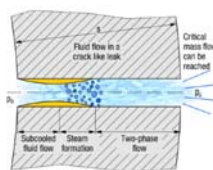
Gefördert durch:
Bundesministerium für Wirtschaft und Technologie
aufgrund eines Beschlusses des Deutschen Bundestages

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Improved Methods for the Analysis of Crack Like Leaks in Piping (1)

- Improved methods for the analysis of crack like leaks in piping are needed
 - a) to prove the effectiveness of the leak-before-break concept
 - b) for the thermal hydraulic analysis of LOCA
- Current models for the calculation of critical discharge flow rates through crack like leaks are based on effective friction factors
- Friction factors deduced from experiments show significant uncertainties



schematic presentation of the discharge flow through a crack

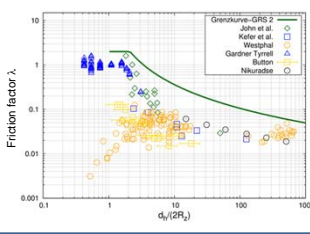
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Improved Methods for the Analysis of Crack Like Leaks in Piping (2)

a) Break preclusion for pressure retaining components:

- Break preclusion concept involves:
 - tough materials: leak-before-break
 - detection of leak before critical crack size is reached
 ⇒ (partly) restriction of leak size in LOCA analysis to 0,1 A rather than 2 A
- Detectability depends on the flow rate determined by the friction factor
- On the basis of 400 experiments GRS has derived a limiting curve representing a conservative envelope of the friction factor with regard to leak detection
- Limiting curve was taken over into rule KTA 3206 of the German Nuclear Safety Standards Commission (KTA)



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Improved Methods for the Analysis of Crack Like Leaks in Piping (3)

b) Coupled thermal hydraulics and structural mechanics analysis of LOCA (1)

- Currently constant leak size is postulated in LOCA analysis
- In reality the size of the crack will change during LOCA
- ⇒ thermal hydraulics coupled with structural mechanics to consider the influence of changing leak size upon safety relevant parameters

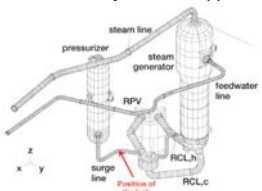
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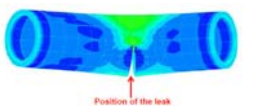
Improved Methods for the Analysis of Crack Like Leaks in Piping (4)

b) Coupled thermal hydraulics and structural mechanics analysis of LOCA (2)

- Performed with
 - ATHLET** (thermal-hydraulics system code of GRS) and
 - ADINA** (finite element program):
- ⇒ to determine the size of the leak, which alters as a consequence of the pressure and temperature drop during the LOCA



- PWR LOCA: 180° circumferential through-wall crack in the surge line with initial leak size 14,2 cm²



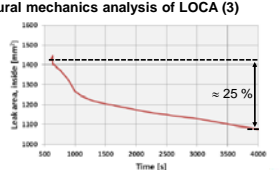
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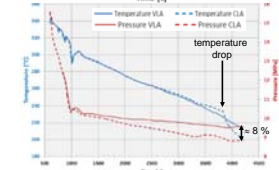
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Improved Methods for the Analysis of Crack Like Leaks in Piping (5)

b) Coupled thermal hydraulics and structural mechanics analysis of LOCA (3)

- Influence on safety relevant parameters after ≈ 1 h:
 - leak area decreases by about 25 % (leak rate about 23 % smaller)
 - pressure remains about 8 % higher
 - higher coolant mass inventory in the RPV
 - temperature drop (due to increased injection rate of low head emergency core cooling system) appears later than with constant leak size






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Selected Results (2)

Development of Advanced Methods in Probabilistic Safety Analysis

Gefördert durch:



aufgrund eines Beschlusses des Deutschen Bundestages

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Development of Advanced Methods for Probabilistic Safety Analysis (1)

Assessment of complex fire scenarios using dynamic PSA (1)

- Time dependencies of interactions between technical equipment and human actions are not considered in classical PSA
 - development of integral deterministic-probabilistic safety analysis (IDPSA)
- Every calculated sequence is characterised e.g. by
 - probability of occurrence
 - randomly determined times for begin and end of human actions
- First application to a fire scenario taking different fire-fighting means into consideration
 - (oil-)fire in compartment with safety relevant cable and systems
 - assumption: automatic activation of fire-fighting system fails
 - 3 scenarios:
 - fire extinguishing by fire patrol
 - fire extinguishing by fire brigade
 - no extinguishing within 1800s

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Development of Advanced Methods for Probabilistic Safety Analysis (2)

Assessment of complex fire scenarios using dynamic PSA (2)

- The method also allows to assess the effect of the different fire-fighting means upon the compartment temperatures and thereby on the failure probabilities of safety relevant systems:
 - no extinguishing:** with 98% the maximum temperature of compartment > 200 °C
 - fire extinguishing by fire brigade:** marginal change of the max. compartment temperature, as fire-fighting actions are carried out "rather" late
 - fire extinguishing by fire patrol:** with 43 % the max. temperature of compartment > 200 °C

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Selected Results (3)

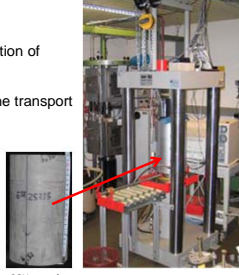
Deep Geological Disposal of Radioactive Waste

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Safety Research for Final Repositories

- The current German waste disposal concept requires the long-term insolation of highly active radioactive waste in a containment providing rock zone
- Focus on rock salt and clay
- Geological barriers are disturbed by construction of waste repository.
- Disturbed zones are potential pathways for the transport of radionuclides into biosphere!
- Laboratory experiments on damaging and healing of clay samples



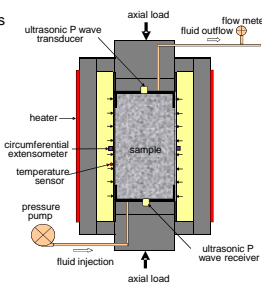
COX sample experimental setup at the GRS' Geoscientific Laboratory

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Experiments on Deformation and Healing of Clay Samples (1)

Laboratory Studies

- Heated uniaxial / triaxial compression tests
 - pressure: max. 70 MPa (axial); max. 50 MPa (lateral)
 - temperature: max. 150 °C
- Measurements
 - axial and radial strain
 - volume changes
 - crack formation (ultrasound)
 - permeability to water and gas flow



Schematic assembly of the test on claystone sample

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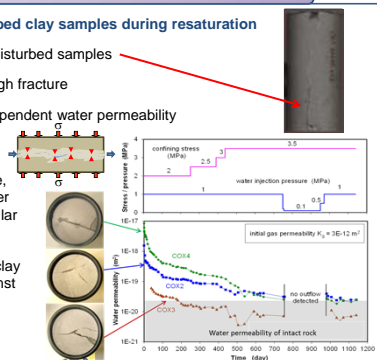
Experiments on Deformation and Healing of Clay Samples (2)

Healing studies of disturbed clay samples during resaturation

- Triaxial load on initially disturbed samples
- Axial flow of water through fracture
- Measurement of time dependent water permeability

Results:

- With increasing pressure, permeability reduces over time down to values similar to undisturbed samples
- Constitutive models for clay rocks are validated against experimental data



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Summary

- 1) The phase out of nuclear energy in Germany (till 2022) required a re-orientation of the nuclear safety research. Focus will be set on
 - a) support of safety during the remaining operation of the German reactors,
 - b) safety of final geological disposal of highly radioactive waste,
 - c) safety of advanced nuclear reactors (e.g. Gen IV, SMR) pursued internationally
- 2) German nuclear safety research community needs to maintain the international integration.

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THANK YOU !

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